CHAPTER 21

GRAPHITE AND CARBON-CARBON COMPOSITES

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INTRODUCTION

With respect to brazing, graphite and carbon-carbon (C/C) composites are somewhat similar to structural ceramics and ceramic-matrix composites. However, although both types of material have high melting points and relatively low coefficients of thermal expansion, structural ceramics are compatible with oxidizing environments, while carbon-based materials typically begin oxidizing at temperatures ranging from 842°F to 1200°F (450°C to 650°C), depending on the perfection of the carbon structure and its purity.

In addition, ceramics generally have little or no porosity, while many carbon materials have significant amounts of open porosity. This porosity complicates the brazing process by wicking molten brazing filler materials away from the joint. On the other hand, carbon materials have higher thermal conductivity, and coupled with their low coefficients of thermal expansion and high strength, they are much less sensitive to thermal shock. The hot strength of graphite increases with temperatures from up to 3630°F to 4530°F (2000°C to 2500°C). Therefore, at such high temperatures, the graphite and C/C composites are the only materials that can maintain high strength and toughness. Finally, carbon materials are also more creep resistant than ceramics.

Carbon materials vary widely in their degree of crystallinity; crystal orientation; and in the size, quantity, and distribution of porosity in the microstructure. These factors, which are strongly dependent on the precursor materials and on processing, govern the physical and mechanical properties of these products. This potential for variation in properties [such as the coefficient of thermal expansion (CTE)] can be advantageous because properties that are significant from a brazing standpoint can be readily modified by processing. For example, coefficients of thermal expansion can be varied from $0.8 \times 10^{-6} \text{°F}^{-1}$ (1.4 $\times 10^{-6} \text{°C}^{-1}$) in the fiber direction in fiber-reinforced composites to $4.6 \times 10^{-6} \text{°F}^{-1}$ (8 $\times 10^{-6} \text{°C}^{-1}$) for isostatically molded isotropic graphites.

APPLICATIONS

Graphite and C/C composites find widespread use in nuclear, aerospace, and electronic applications. They are also used as electrodes in metallurgical processes, fixtures and heating elements in vacuum furnaces, chemical equipment and instruments, filters in biochemistry, extractive metallurgy, and wastewater treatment. Specialized uses include guide vanes, electric motor brushes and switches, bushings and bearings, high-temperature heat exchangers, and plumbing, as well as heart valves, and high-performance brake linings.